Master Thesis in Marine Technology – 2016

Simulation of Anchor Loads On Pipelines

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Introduction

Incidents where anchor and pipeline interact are rare, but can have drastic consequences. In the report *Pipeline and Riser Loss of Containment* published in 2001 for the UK sector, 44 incidents involving anchors and pipelines were found for the time period 1990-2000 (HSE, 2009). An example of anchor-pipeline interaction in the Norwegian sector is the Kvitebjørn gas pipeline incident (Gjertveit, Berge, & Opheim, 2010). During inspection in 2007 it was discovered that the pipeline had been dented and local buckling had occurred due to impact with an anchor (Gjertveit et al., 2010).

Despite the small amount of interactions, the consequences of these and the increasing amount of pipelines and ship traffic across these pipelines in the North Sea makes the topic of anchor-pipeline interaction highly relevant.

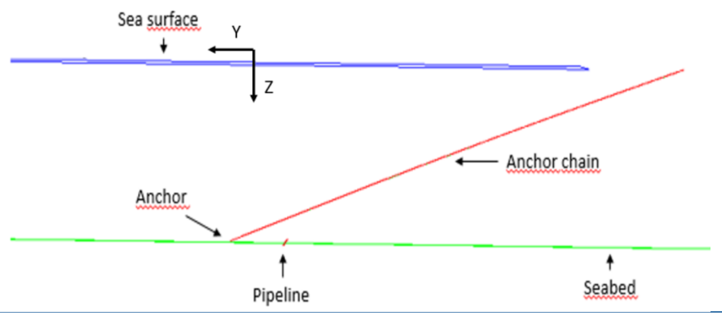
Objective

There is limited literature regarding anchor-pipeline interaction, but there is a tendency to classify the interaction as either: impact, hooking or pull-over. This classification may prove simplistic, and cause loss of information regarding the behaviour of the anchor.

The objective of the thesis has been to categorize the anchors behaviour when exposed to different parameters, but also to improve the categorization of the behaviour. This is to inspect when hooking and sliding occurs, and create a better system to describe the pull-over behaviour. By understanding the anchors behaviour, it may increase the understanding of the pipelines response to the interaction.

Methodology

To analyse the interaction between anchor and pipeline the computer software SIMLA is applied. SIMLA is a specified software used to perform analyses on umbilical structures, such as pipelines (MARINTEK, 2012). It allows for both non-linear static and dynamic analysis, and is an optimal tool for inspecting anchor-pipeline interaction. A complete set up of the parametric study is seen in figure below.



Scope

The scope of the thesis has been narrowed by only inspecting six anchor sizes, only one water depth and by not inspecting the local response of the pipeline, as that would require a more detailed analysis. Due to time limitations and the complexity of the topic, modelling of the soil has been simplified. Parameters studied in the parametric study are displayed in the table below.

Anchor Mass [kg]	Anchor Class	Pipe Diameter [Inches]	Vessel velocity [knots]	Anchor Chain Length [m]	Attack Angle [deg]
3780	Z	30	2	522.5	90
4890	D	40	10	550	60
6000	G			577.5	30
7800	K			632.5	
9900	O			660	
15400	X			742.5	

Results Parametric Study – Categorization

Of 72 analysis where anchor mass, pipe diameter, vessel velocity and attack angle were altered, eight were deemed inconclusive. To classify the responses seen in the analysis a system was created, seen in Fig.1. The difference between a pull over and a bounce over response in seen in Fig. 2 and Fig. 3. Two hooking scenarios is shown in Fig. 4, (a) showing how hooking occurs when the angle of attack is 90 degrees, and (b) showing hooking when the angle of attack is 60 degrees and twisting has occured. Fig.5 shows a sliding with twist and pull over response.

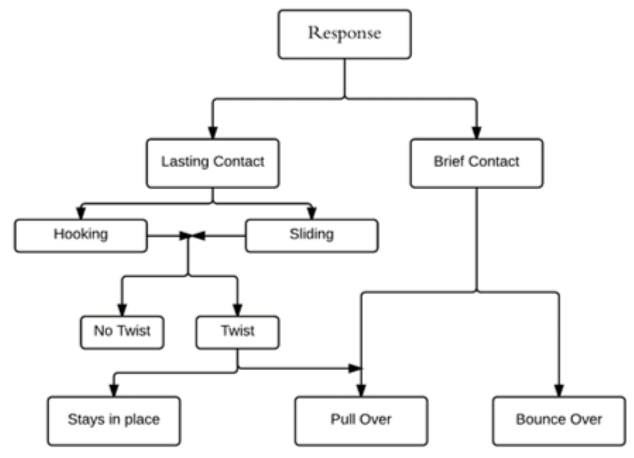
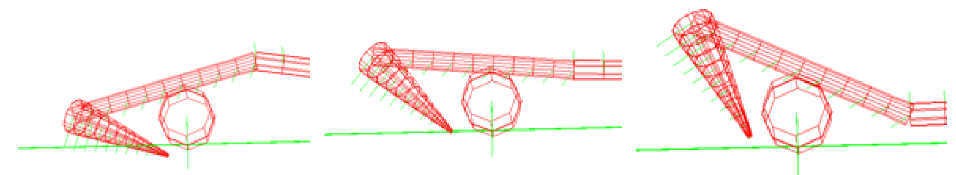
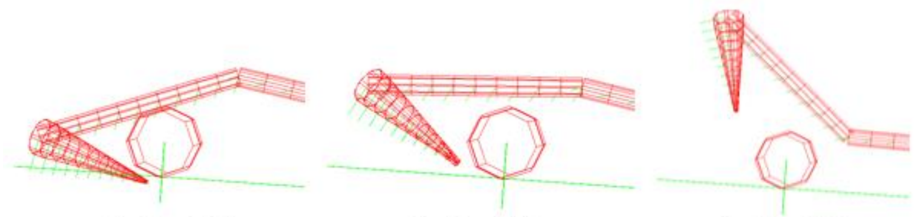


Figure 1: Summary of categorisation



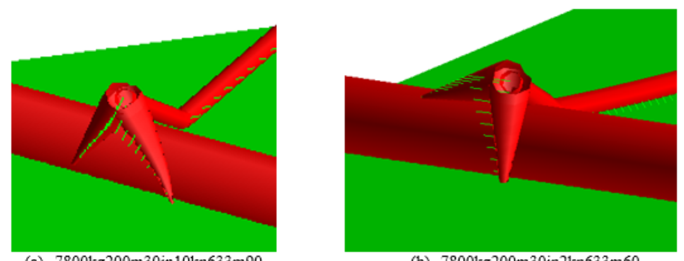
(a) Time 128.4 [s] (b) Time 128.62 [s] (c) Time 128.87 [s]

Figure 2: Simulation snapshots of realistic pull over response in model 9900kg200m30in2kn660m90



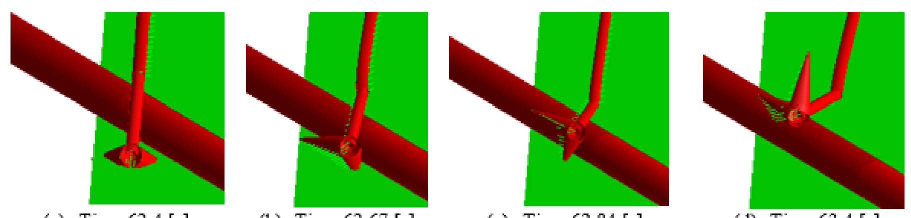
(a) Time 64.65 s (b) Time 64.72 s (c) Time 64.89 s

Figure 3: A realistic bouncing off response seen in model 6000kg200m30in2kn578m90



(a) 7800kg200m30in10kn633m90 (b) 7800kg200m30in2kn633m60

Figure 4: Two realistic cases of hooking, (a) without twisting and (b) with twisting



(a) Time 62.4 [s] (b) Time 62.67 [s] (c) Time 62.84 [s] (d) Time 63.4 [s]

Figure 5: Sliding with twist and pull over response in 7800kg200m30in10kn633m30

Results Parametric Study - Ratios

The ratios are calculated as seen in the equation to the right. The whole purpose of applying these ratios is to demonstrate trends which emerge with different parameters. Bounce over and pull over are grouped together as brief contact. Fig.6 shows the general ratio for the responses, Fig.7 shows the distribution of bounce over and pull over, Fig.8 shows the effect of attack angle and mass on hooking ratio and Fig. 9 shows the effect of attack angle and mass on sliding ratio. Fig. 10 shows the effect pipe size, vessel of velocity and angle of attack has on hooking, while Fig. 11 shows the effect it has on sliding.

$$Ratio = \frac{Number\ of\ response}{Total\ number\ of\ response}\ [\%]$$

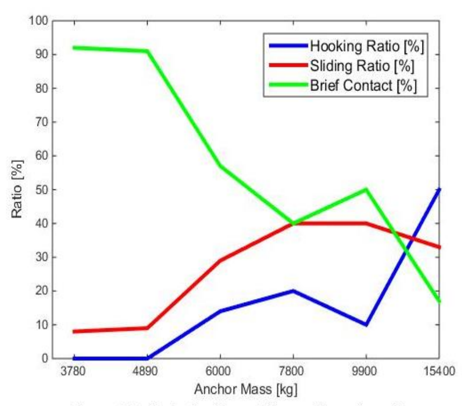


Figure 6: Ratio for hooking, sliding and bouncing off

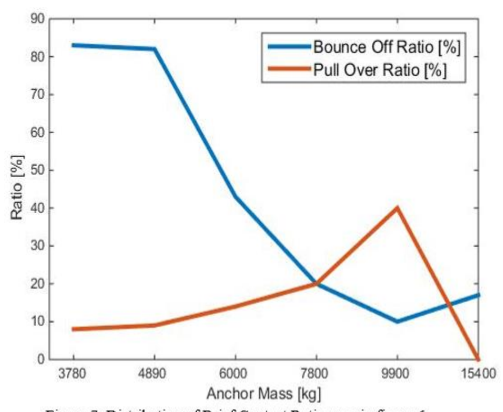


Figure 7: Distribution of Brief Contact Ratio seen in figure 6

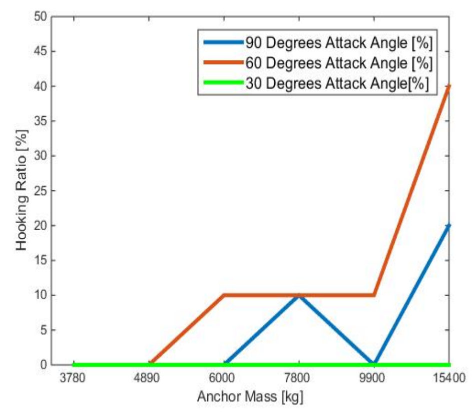


Figure 8: Hooking ratio depending on angle of attack and anchor mass

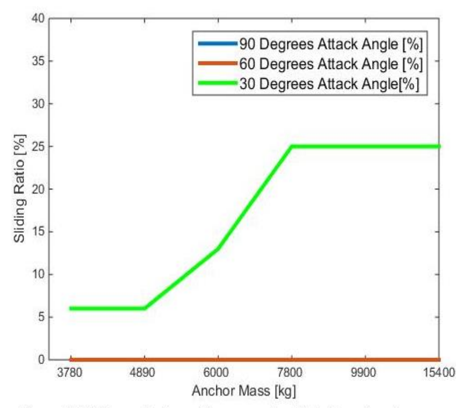
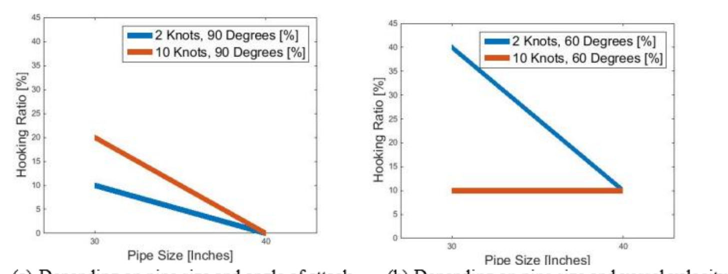


Figure 9: Sliding ratio depending on angle of attack and anchor mass



(a) Depending on pipe size and angle of attack (b) Depending on pipe size and vessel velocity

Figure 10: Hooking ratio depending on pipe size and vessel velocity

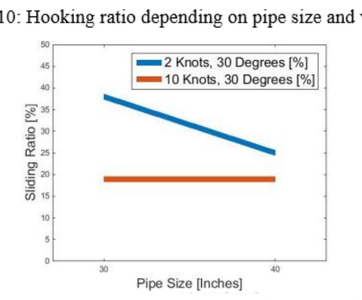


Figure 11: Sliding ratio depending on pipe size and vessel velocity

Conclusion

The general trend shows an increase in hooking and sliding with increased mass of anchor. The largest amount of hooking occurs for an attack angle of 60 degrees, followed by 90 degrees. All of the hooking which occurred for the 60 degrees cases were caused by anchor twisting as seen in figure 4 (b). No hooking occurred for the 30 degrees case, while all cases of sliding occur for this angle. Further the trend implies that a larger hooking ratio is obtained with the smaller pipe size and with lower vessel speed. A larger sliding ratio is also obtained with lower vessel speeds.

The trend of a higher hooking ratio, when larger anchors interact with smaller pipes at a low velocity was also found by Vervik (2011) and Wei (2015). However, comparing results do pose several issues as Wei (2015) uses vessel speeds of 6 and 12 knots, and different outer pipe diameter. Despite this, the same conclusion is drawn that more hooking occurs when large anchors interact with small pipes at lower velocities.

The dividing of the pull-over into two different responses have also shown that the larger the anchor, combined with a long and heavy anchor chain increases the likelihood of the anchor being pulled over rather than bouncing over. It should be noted that there were some numerical errors when modelling the interaction which might have caused a larger portion of the brief contact responses being classified as bounce over.

References

Gjertveit, E., Berge, J. O., & Opheim, B. S. (2010). *The Kvitebjorn Gas Pipeline Repair*. Paper presented at the Offshore Technology Conference Houston, Texas.

HSE. (2009). *Guidelines for Pipeline Operators on Pipeline Anchor Hazards*. Aberdeen.

MARINTEK. (2012). Fact Sheet - SIMLA. Retrieved from https://www.sintef.no/globalassets/upload/marintek/pdf-filer/factsheets/simla.pdf

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